Fermi National Accelerator Laboratory

FERMILAB-Conf-86/15
0102.000

SSC EVENT CHARACTERISTICS AND IMPLICATIONS FOR DETECTOR DESIGN*

Brad Cox, Presentor

C. Buchanan
University of California at Los Angeles, Los Angeles, California 90024 USA

B. Cox and J. Lach
Fermi National Accelerator Laboratory, Batavia, Illinois 60510 USA

R. Diebold
Argonne National Laboratory, Argonne, Illinois 60439 USA

R. Field
University of Florida, Gainesville, Florida 32601 USA

M. G. D. Gilchriese
Cornell University, Ithaca, New York 14853 USA

T. Gottschalk
California Institute of Technology, Pasadena, California 91125 USA

S. Loken
University of California at Berkeley, Berkeley, California 94720 USA

S. Protopopescu
Brookhaven National Laboratory, Upton, New York 11973 USA

T. Sjöstrand
University of Lund, Lund, Sweden

D. Smith
University of California at Riverside, Riverside, California 92502

January 1986

*Presented at the Supercollider Physics Topical Conference, University of Oregon, Eugene, Oregon, August 9 and 10, 1985.

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

SSC Event Characteristics and Implications for Detector Design

Presented by B. Cox
at the Supercollider Topical Conference
University of Oregon, Eugene, Oregon

C. Buchanan,[1] B. Cox,[2] R. Diebold,[3] R. Field,[4] M. G. D. Gilchriese,[5]
T. Gottschalk,[6] J. Lach,[2] S. Loken,[7] S. Protopopescu,[8]
T. Sjöstrand,[9] and D. Smith[10]

ABSTRACT

During the course of a one week workshop recent progress on event simulation at SSC energies was reviewed and implications for detector design were briefly evaluated. Questions needing to be answered by future work were formulated.

---

[1]University of California at Los Angeles, [2]Fermi National Accelerator Laboratory, [3]Argonne National Laboratory, [4]University of Florida, [5]Cornell University, [6]California Institute of Technology, [9]University of Lund, [10]University of California at Riverside

INTRODUCTION

The extrapolation from present accelerator energies to 40 TeV at the SSC is fraught with uncertainties. In spite of these uncertainties the prediction of event characteristics at 40 TeV is being attempted by several Monte Carlo programs[1] that are presently in use. In particular ISAJET, LUND, and FIELDJET predictions are often used in the evaluation of various detector designs. As a part of the Oregon Workshop on Super High Energy Physics an examination of the predictions of these Monte Carlos was made by a group of theorists and experimentalists. Questions particularly pertinent to detector design were formulated by this group and preliminary attempts to answer some of these questions were made.

Progress and improvements to the various Monte Carlos have been made since Snowmass 84[2]. The overall effect of these changes has been to make the simulation of 40 TeV events more realistic. In the process the complexity of the events has increased making the extraction of interesting signals more difficult than had been thought at the time of Snowmass 84. While the various Monte Carlos have been tuned to agree with data at present collider energies (mainly $\sqrt{s}$=540 GeV at the CERN SPS with some attention given to ISR data) disagreements appear between the various Monte Carlos in their predictions at $\sqrt{s}$=40 TeV. Given the greatly differing approaches to the simulation of high energy interactions by the three Monte Carlos mentioned above and their incomplete status at this point disagreements are not surprising. Indeed the discrepancies between the various Monte Carlo predictions have been taken as an indication of the uncertainty in the extrapolations to $\sqrt{s}$=40 TeV that can be made at this time.

MONTE CARLO CHARACTERISTICS

Since other talks at this conference will concentrate on the details of the various Monte Carlos to event simulation at $\sqrt{s}$=40 TeV, only general features of these Monte Carlos will be mentioned here. As indicated above ISAJET, LUND and FIELDJET were the Monte Carlos that were examined and compared in the brief time available to this group. Figure 1 shows the various components of high P_T events (hard scattering events) as incorporated in the Monte Carlos. These components include:

1. Structure functions for the incoming hadrons.
2. Gluon emission by initial state partons.
3. Hard scattering matrix elements.
4. Final state parton evolution.
5. Hadronization of final state partons.
6. Beam remmants.

Both ISAJET and FIELDJET use the independent fragmentation model which treats all partons in an event as independent of all other partons. LUND uses the string model with gluons occurring naturally as kinks on the strings connecting the partons in the high energy events. The independent fragmentation model can lead to multiple counting and does not explicitedly conserve energy, momentum or flavor. The string formulism of the LUND Monte Carlo is more ambitious and, starting from more fundamental physics considerations, does conserve energy and flavor. In addition soft gluons are incorporated in the more natural and continuous way mentioned above. All of the Monte Carlos have trouble with low P_T (total cross section or "minimum bias" events) because of the lack of a non perturbative theory of QCD which is needed as $P_T \Rightarrow 0$. The major changes in these Monte Carlos since Snowmass 84 have been:

1. Initial state fragmentation has been incorporated into ISAJET and LUND. This adds to the total multiplicity predicted by LUND and ISAJET bringing the total predicted multiplicities more in line with FIELDJET which already contained initial state fragmentation. In addition, the incorporation of initial state fragmentation (because of the log (Q^2) increase in the probability of emitting a hard gluon as the Q^2 of the primary hard scattering increases) generates relatively high P_T gluon jets (see inset in Figure 1). Thus 2 to 2 hard scattering events contain more jets on the average than would be thought naively and makes event interpretation more difficult.

2. A multiple scattering model[3] in which more than one pair of partons from the beam hadrons are caused to interact has been incorporated into the LUND Monte Carlo in an attempt to reproduce the multiplicity distributions in "minimum bias" events and to reproduce the tails of jets.

3. Backward evolution[4] of the event generation has been incorporated into ISAJET and LUND to speed up event generation.

QUESTIONS

In spite of the incomplete nature of these Monte Carlos, the differences in their predictions of 40 TeV physics and the problems that they have in predicting observed phenomena at $\sqrt{s}$=540 GeV, they have been used as tools for detector design. The questions that they have been used to investigate fall into three categories

1. Questions about single particle distributions → What will the average multiplicity of an event at 40 TeV be? What will the average occupancy of a calorimeter element be? At what rate will individual elements of the detector have to function at the proposed high luminosities ($L \sim 10^{33} \rightarrow 10^{34}$ cm^2/sec) in order to avoid instrumental effects. The ability to answer these questions depends on the ability of the Monte Carlos to generate total cross section events.

2. Questions about the characteristics of jets at 40 TeV → What are the expected angular sizes of jets, especially heavy quark jets? What will the energy distribution of the fragments of the jets be? How many jets on average will be produced in 2 to 2 hard scattering events and how are these jets distributed with respect to each other? What is the origin of these jets (initial state fragmentation, hard scattered partons, fragmentation of final state partons, beam hadron remmants)? How separable will final state leptons be from heavy quark jets? How well will we be able to reconstruct jet masses and shapes and distinquish heavy quark jets from gluon and light quark jets? What is the effect of multiple interaction pile up on any of these aspects of jet pattern recognition and reconstruction?

3. Questions about the reconstruction of specific final states from observed and reconstructed jets → What is the effect of missing energy due to ν's on the reconstruction of specific interesting final states? What is the effect of a minimum energy threshold or angular cone cuts on the reconstruction of final states? What is the effect of detector resolutions on final state reconstruction?

These questions are neither new nor inclusive. Only a few aspects of each issue could be investigated. But in view of the changes in the Monte Carlos since Snowmass 84 it is appropriate to begin to examine them again.

INDIVIDUAL PARTICLE ASPECTS OF 40 TeV EVENTS

As mentioned above knowledge of the average number and distributions of secondary particles from 40 TeV total cross section type events is important for the design of high luminosity experiments. However the prediction of particle multiplicities at 40 TeV is uncertain by large factors. Even with the inclusion of initial state interactions and with tuning to agree at $\sqrt{s}=540$ GeV the LUND and ISAJET Monte Carlos disagree by almost a factor of 2 on average charged multiplicities at 40 TeV. This is shown in Figure 2. FIELDJET gives an even larger average multiplicity at 40 TeV. This is a first manifestation of the difficulties that the Monte Carlos have in simulating total cross section type events.

More detailed questions can be asked which further demonstrate the uncertainties in the Monte Carlos. In Figure 3 the distributions of multiplicities observed[5] by UA5 at $\sqrt{s}=540$ GeV are shown. Both the low and high multiplicity parts of this distribution give problems. In general diffractive phenomena (which produce low multiplicities) are not yet incorporated into the Monte Carlos. As seen in Figure 3 there is also difficulty in reproducing the high multiplicity tail of the spectrum. The LUND Monte Carlo (which is shown as an example) must incorporate multiple hard scatterings of different pairs of partons from the beam hadrons in order to get the high multiplicity tail of the distribution. The average number of interactions which best fits the distribution is greater than one. The number of multiple interactions is tuned by adjusting a P_T^{MIN} cutoff in the Monte Carlo. As mentioned above there must be a P_T^{MIN} cutoff since perturbative QCD cannot be used as $P_T \nrightarrow \emptyset$. As P_T^{MIN} decreases the number of multiple interactions increase and the multiplicity of the event increases. It is not clear, as we will see later, that this multiplicity distribution can be fit with same number of multiple interactions required to fit the low energy tails of the hard scattering jets.

In spite of these problems with LUND and the other Monte Carlos the question of average occupancy of a calorimeter cell in hard scattering events has been investigated. The occupancy of detector cells of size $\Delta\theta\Delta\phi=10^{\circ}\times15^{\circ}$ has been calculated using FIELDJET at $\sqrt{s}=540$ GeV for cells with $|\eta|<1$ (240 cells) as function of global E_T and compared to the data[6] of UA2 in Figure 4. A cell was considered to be occupied if the E_T in that cell exceeded 0.4 GeV. The agreement of the Monte Carlo with the UA2 data is quite good. A feeling for the increase in complexity of events at $\sqrt{s}$=40 TeV can be acquired by comparing the average occupancy of 30-40 out of 240 cells at $\sqrt{s}$=540 GeV to the average occupancy of 333 out of 960 cells predicted by FIELDJET at $\sqrt{s}$=40 TeV for $|\eta|<4$ and a cell size of $\Delta\eta\Delta\phi$=.2x15^{o} with E_T^{MIN}=1.0 GeV. The effect of this large occupancy on jet definition will be touched on in the next section.

JETS FROM HARD SCATTERS AT 40 TeV

The preceeding discussion has given a taste of the complexity of events with hard scatters at $\sqrt{s}$=40 TeV but what can be determined about the jet structure of such events? In spite of the high occupancy of the spectrometer cells with many low energy fragments which might present problems for central tracking devices we might reasonably expect that jets from the fragmentation of 2->2 hard scattered partons would be quite collimated and would stand out prominently above the low E_T backgrounds. In this case the count of observed jets might naively be thought to be usable as a signature of the physics taking place in the interaction. To test this hypothesis individual events at $\sqrt{s}$=40 TeV were generated using both the ISAJET and LUND Monte Carlos and examined to determine their gross properties. Figure 5a, b and c shows three typical events generated by ISAJET and displayed in the ϕ, η plane. These 2->2 sctterimg events have E_T>1.5 TeV and are therefore defined to be interesting As can be seen from these typical events the number of "substantial" jets (E>360 GeV) is not simply two. Beam remnants, initial state gluon emission, final state gluon emission all conspire to produce many jets at $\sqrt{s}$=40 TeV. In Figure 5b a contour of $\Delta\omega=\sqrt{(\Delta\eta)^2+(\Delta\phi)^2}=0.5$ is shown as an estimate of what solid angle a reasonable jet finding algorithm might subtend.

This problem can be further quantified with just a few events. If an interesting jet is defined to have at least one calorimetry cell with E_T>30 GeV and the total jet E_T>1000 GeV (calculated by adding up any of the eight neighbor cells and ignoring cells already included in previous jets) then ISAJET and LUND 2 to 2 hard scattering events have the number of jets shown in Figures 6a and b. As can be seen the two results are quite consistent and give 1.5 jets more on the average than expected from the 2 to 2 hard scatters. One half of these extra jets are due to initial state parton fragmentation and were not in the LUND and ISAJET Monte Carlo calculations at the time of Snowmass 84. In fact, as shown in Figure 7, an appreciable part of the E_T in a hard scattering event predicted by the LUND Monte Carlo event at $\sqrt{s}$=40 TeV comes from partons other than the hard scattered partons. Similar results can be obtained with FIELDJET. At $\sqrt{s}$=540 GeV the FIELDJET prediction has been compared with the data from UA2 as a function of global E_T for a jet cluster algorithm in which each cluster is required to have E_T>10 GeV and cell sizes are $10^{\circ} \times 15^{\circ}$. $|\eta|$ is restricted to be less than 1. As seen in Figure 8 the agreement with the UA2 data is quite good. The number of clusters increases as E_T increases as shown in Figure 8 by a factor of almost 2 in going from an E_T of 60 GeV to E_T of 180 GeV. This bears out the assertion made in the introduction that large angle hard gluon emission in the initial state increases with the Q^2 of the hard scatter.

We have also examined the rapidity of extra jets that are present in the 40 TeV interactions. If these surplus jets were confined to high rapidities it might still be possible to count "fundamental" jets in an event. However the extra jets predicted by the LUND Monte Carlo have the distribution shown in Figure 9. As can be seen the extra jets are at large angles in the region in which we observe the hard scattering jets. 90% of the extra jets are within $|\eta|<2$.

For the hard scattering jets themselves the ability to reconstruct these jets in 40 TeV interactions is an important question. We have investigated the $\Delta\omega=\sqrt{(\Delta\eta)^2+(\Delta\phi)^2}$ cone that must be used in order to capture a given percentage of the jet energy. LUND and ISAJET are compared in Figure 10 for different size cones by plotting percentage of the events having a given fraction of energy within the cone centered on the parton direction. The peak at zero fraction which is present in all but $\Delta\omega$=1.0 plots comes from events which have a hard gluon emission early in the fragmentation process such that two or more partons are produced at large angles with respect to the original parton direction. The probability that a gluon is emitted at a given angle θ with respect to the original parton direction is proportional to θ^2 and therefore leads to this rather high probability that very little energy is in a narrow cone centered on the original parton direction. The results from both Monte Carlos are quite consistent but there is some slight indication that the ISAJET Monte Carlo produces slightly more collimated jets than LUND. Finally, if we examine the dependence of the average fraction of E_T contained as a function of $\Delta\omega$ for different P_T jets, we find only a slight increase in collimation over the range P_T=0.25 TeV/c $\mapsto$ P_T=4.0 TeV/c.

In spite of these fluctuations in fragmentation of the hard partons, well behaved jets must be used to extract the physics of 40 TeV interactions. The shapes of average jets both in multiplicity flow and E_T as a function of pseudorapidity have been examined at $\sqrt{s}$=540. Figure 11 shows the number of charged particles as a function of rapidity for a sample of jets from UA1[7] as compared to FIELDJET. Figure 12 shows the E_T distribution for these jets as compared to FIELDJET, ISAJET and LUND. The first observation that can be made is that the multiplicity flow distribution of the data are not as peaked as the E_T distribution implying tails of the jet which have a substantial number of low energy particles. In addition the Monte Carlos fail to predict the tail of the E_T distribution with the same accuracy. This tail has become known as the pedastal effect. ISAJET and LUND achieve fair agreement with the UA1 transverse energy flow data while the FIELDJET prediction falls below the data as shown in Fig. 12. However both ISAJET and the LUND Monte Carlos required major additions in order to achieve this agreement. ISAJET was able to replicate the level of these tails by the inclusion of initial state fragmentations. In the LUND model agreement with the UA1 data was achieved by increasing the number of multiple interactions of pairs of partons by a factor of 4 over that predicted using a total cross section of 47 mb (this is tantamount to using a cross section of 10 mb in the LUND model formalism). Under the circumstances it is difficult to completely trust the extrapolation of either independent fragmentation or the string fragmentation models to $\sqrt{s}$=40 TeV. In spite of this we show in Figure 13a and b the predictions of FIELDJET for multiplicity flow and E_T of hadrons per 0.2 bin of η for $\sqrt{s}$=40 TeV interactions with $1<E_T<2$ TeV and $2<E_T<3$ TeV. As shown the level of the tails of the jets have increased to 3-4 hadrons per bin and an E_T bin of 2 GeV. It is in this sort of environment that accompanying leptons must be detected, identified and measured.

An investigation of the $\Delta\omega=\sqrt{\Delta\eta^2+\Delta\theta^2}$ separation of decay leptons from the closest neighboring particle in top quark jets was performed in order to determine the magnitude of the detection problem. Jets from top quarks with P_T of 100 GeV/c and 500 GeV/c were generated with ISAJET. In events in which the P_T of the lepton from the semilepton decay of the top was greater than 10 GeV/c and the $|\eta|$ of the lepton was <5.0, the $\Delta\omega$ separation between this lepton and nearest jet fragment with P_T>2 GeV was plotted. (The assumption that P_T<2 GeV/c tracks may be ignored for the lepton identification process may be optimistic.) The results of this study are shown in Figures 14a and b for 100 and 500 GeV/c top quark jets. The leptons have a nearest neighbor with P_T >2 GeV at an average separation of $\Delta\omega$=0.14 and $\Delta\omega$=0.07 for the 100 and 500 GeV/c jets respectively. There are however a small number of jets which have relatively isolated leptons even at 500 GeV/c. Detection and tagging of high P_T heavy quark jets by their lepton content appears to be difficult with reasonable, achievable granularities for very high P_T jets.

Reconstruction of Interesting Final States from Jets

While a complete consideration of reconstruction of final states from jets was obviously not possible in the limited time available, questions about what procedures could be used were formulated. If a heavy object decays into two heavy quarks then, depending on the details of the backgrounds, one would attempt to

1. Identify the two decay jets as heavy quark jets to suppress background.
2. Reconstruct the mass from the heavy quark jets.

Among the problems that have been noted in other works is the off mass shell nature of the light gluon and quark jets that obscure searches for heavy quark jets based on their reconstructed masses even if a perfect detector was available. Figure 15, taken from Ref. 8 shows how top quarks can be confused with off mass shell gluon and light quark jets based on reconstructed mass.

If one could isolate the $t\bar{t}$ from a $X \Rightarrow t\bar{t}$ decay then the reconstruction of X is disturbed even for a perfect detector by (1) energy missed due to ν in the heavy quark decays, (2) energy missed due to the cone cuts that must be made to isolate the jets, (3) energy missed due to the minimum energy threshold that must be imposed on the event in a cluster finding algorithm. While in principle it may be possible to develop algorithms to compensate for, on the average, (2) and (3) there will always be some degradation due to fluctuations. An example of the effects of (1), (2), and (3) was presented in Snowmass 84 by the group who[9] were investigating the detection of Higgs $\Rightarrow t\bar{t}$ at $\sqrt{s}$=40 TeV. Even with a perfect detector and ignoring the overlap of the $t\bar{t}$ fragments the ability to reconstruct the Higgs was limited. This is shown in Figures 16a, b, and c.

Conclusions:

Three Monte Carlos, FIELDJET, ISAJET, and LUND have been used to investigate what may happen in $\sqrt{s}$=40 TeV interactions. Since Snowmass 84 these Monte Carlos have become more realistic in their predictions of these jets which are products of initial and final state fragmentation. However there are still substantial differences between these Monte Carlos and the data at $\sqrt{s}$=540 GeV and between the Monte Carlos themselves at $\sqrt{s}$=40 TeV However certain features of their $\sqrt{s}$=40 TeV predictions should be noted. Many more "substantial" jets will be present in 40 TeV interactions than just those arising from the hard scattered partons. Using "substantial" jet count as an indicator of interesting physics will be difficult. A large percentage of these extra jets come from initial state fragmentation. In addition, if global E_T is used as a trigger, an appreciable part of the E_T of a hard scattering event will come from these intial state fragments making the triggering less effective. These "extra" jets are not restricted to large η region but can be near η=0. The final state fragmentation of large Q^2 hard scattered partons also introduces problems since large angle gluon emission frequently make it difficult to identify all fragments that are associated with the hard scattered partons. Finally the jets associated with the hard scattered partons will have an energy "pedestal" associated with them which is difficult for the Monte Carlos to predict at $\sqrt{s}$=40 TeV but which would be substantially larger than is present at $\sqrt{s}$=540 GeV.

All of the Monte Carlos which were examined agreed qualitatively on these and other issues. Qualitatively the Monte Carlos disagreed in some of their predictions by quite significant amounts. These disagreements and the fact that the approaches to predicting the high energy interactions was so different in the various Monte Carlos allowed us to gauge the ability of the Monte Carlos to predict $\sqrt{s}=40$ TeV physics. The multiplicity of approaches was therefore concluded to be quite desirable for this reason. However a set of intercomparison standards need to be established between the Monte Carlos in order to facilitate comparisons. Finally more sustained effort will be needed to improve the Monte Carlos and facilitate extracting all that they can tell us about 40 TeV physics.

Acknowledgements

This work was carried out in a one week workshop which was part of the Oregon Workshop on Super High Energy Physics at the Institute for Theoretical Science at the University of Oregon, Eugene, Oregon. We would like to acknowledge the hospitality and stimulating atmosphere provided by the organizers, N. Deshpande, R. Hwa and D. Soper as well as the input from the theorists participating in the workshop. In particular Jack Gunion providing many quantative inputs and insights to our deliberations.

References

1. ISAJET, F.E. Paige and S.D. Protopescu, BNL Report 29777 (1980).
   FIELDJET, R.D. Field, University of Florida preprints UFTP-81-12, UFTP-82-28, UFTP-84-3. High Energy Multijets at the CERN $\bar{p}p$ Collider and the SSC, R.D. Field, to be published.
   LUND (PYTHIA), H.-U. Bengtsson, Computer Phys. Comm. 31 (1984)323
   H.-U Bengtsson, G. Ingelnam, Computer Phys. Comm. 34 (1985)351
   T. Sjostrand, Computer Phys. Comm. 27 (1982) 243
   B. Anderson, G. Gustafson, G. Ingelman, T. Sjostrand, Phys. Rep. 97 (1983) 33.
2. Proceedings of the 1984 Summer Study on the Design and Utilization of the Superconducting Super Collider, Snowmass, Colorado 1982, edited by R. Donaldson and J.G. Morfin.
3. T. Sjostrand, Fermilab-Pub-85/119-T (1985).
4. T. Gottshalk, Caltech preprint, CALT-68-1241 (1985).
5. G.J. Alner et al. (UA5 collaboration) Phys. Lett. 138B (1984) 304,
   K. Alpqard et al. (UA5 collaboration) Phys. Lett. 123B (1983) 361.
6. P. Bagnaia et al., (UA2 collaboration) CERN preprint CERN-EP/84-12,
   J. Hansen (UA2 collaboration), invited talk presented at the First Aspen Winter Physics Conference on Collider Physics, Aspen, Colorado (1985).
7. G. Arnison et al., (UA1 collaboration) CERN preprint CERN-EP/83-118.
8. G.S. Abrams and B. Cox, Proceedings of the 1984 Summer Study on the Design and Utilization of the Superconducting Super Collider (1984) 94.
9. B. Cox and F.J. Gilman, Report of the Standard Electroweak and Higgs Boson Working Group, Proceedings of the 1984 Summer Study on the Design and Utilization of the Superconducting Supper Collider, (1984) 87.

Figure Captions

Fig. 1 Components of 2 to 2 hard scattering events.

Fig. 2 Average charged particle multiplicities as predicted by ISAJET and LUND Monte Carlos as a function of $\sqrt{s}$.

Fig. 3 Charged particle multiplicity distributions at $\sqrt{s}=540$ GeV as measured by UA5. The predictions of the LUND Monte Carlo including the incorporation of multiple interactions between different pairs of partons in the beam hadrons. Three different predictions for different P_T^{MIN} cutoffs are shown along with the number of multiple interactions that these cutoffs correspond to.

Fig. 4 Predicted occupancy of detector cells of size $\Delta\theta\Delta\phi=10^{\circ}\times15^{\circ}$ from FIELDJET compared to data of UA2 at $\sqrt{s}=540$ GeV as a function of global E_T. A cell is considered to be occupied if E_T within that cell is greater than 0.4 GeV.

Fig. 5 a) Typical high E_T event from a 2 to 2 hard scattering interaction as generated by the ISAJET at $\sqrt{s}=40$ TeV and displayed in the η, ϕ projection. This event appears to be a two or three jet event using the jet criteria described in the text.

b) Another "typical" 2 to 2 high E_T event as described above except that there appear to be three substantial jets. The $\Delta\omega=\sqrt{(\Delta\eta)^2+(\Delta\phi)^2}=0.5$ contour indicates the area that a "reasonable" jet algorithm might assume for a jet size.

c) Typical 2 to 2 high E_T event as described above which appears to have 5 or 6 substantial jets.

Fig. 6 a) Distribution of number of jets in $\sqrt{s}=40$ TeV events generated by the LUND Monte Carlo as determined from the criteria described in the text.

b) Distribution of number of jets in $\sqrt{s}=40$ TeV events generated by ISAJET as determined from the same criteria.

Fig. 7 Ratio of the E_T in $\sqrt{s}=40$ TeV interactions generated by the LUND Monte Carlo to E_T in the hard scattered parton jets as a function of P_T for the hard scattering process.

Fig. 8 Distribution of number of E_T clusters in $\sqrt{s}$=540 GeV $\bar{p}p$ interactions as a function of global E_T with E_T>10 GeV and $|\eta|<1$ as measured by UA2 compared with the prediction of FIELDJET.

Fig. 9 a) Rapidity distribution for jets with E_T>100 GeV other than the hard scattering jets as generated by the LUND Monte Carlo for $\sqrt{s}$=40 TeV pp interactions.

b) Same as 9a but for jets with E_T>50 GeV.

Fig. 10 Fraction of parton energy predicted by LUND and ISAJET to be within various $\Delta\omega=\sqrt{(\Delta\eta)^2+(\Delta\phi)^2}$ cones centered on the original parton direction.

Fig. 11 Charge particle multiplicity flow relative to the highest E_T jet in $\bar{p}p$ collisions at $\sqrt{s}$=540 GeV with $|\eta|<4$ and E_T(jet)>35 GeV. Cell size of $\Delta\eta\Delta\phi$=.2x15° has been used. The data is that of the UA1 experiment and the prediction is that of FIELDJET.

Fig. 12 Transverse energy flow with the same conditions as those of Fig. 11. The data is from UA1 and the predictions are those of FIELDJET (solid curve), ISAJET (dashed curve) and LUND (dot-dashed curve).

Fig. 13 a) Charged particle multiplicity flow as predicted by FIELDJET at $\sqrt{s}$=40 TeV for global E_T less than 2 TeV and for global E_T between 2 and 3 TeV.

b) Transverse energy flow as predicted by FIELDJET at $\sqrt{s}$=40 TeV for the same conditions as those of Fig. 13a.

Fig. 14 a) Separation of leptons from top quark decay from nearest jet fragments with P_T>2 GeV/c. Top quark P_T=100 GeV/c and minimum lepton P_T=10 GeV/c.

b) Same as a) except top quark P_T=500 GeV/c.

Fig. 15 Reconstructed top quark masses from gg->$t\bar{t}$ compared to expected mass spectrum of gluon from gg->gg.

Fig. 16 a) Effect of missing neutrinos from top quark decay on the reconstruction of the mass of Higgs->$t\bar{t}$ at $\sqrt{s}$=40 TeV for 120 GeV/c^2 Higgs.

b) Combined effect of missing neutrinos and missing energy in the reconstruction of the Higgs mass.

c) Combined effect of missing neutrinos and omission of all E<1 GeV fragments from the t quark jets on the reconstruction of the Higgs mass.

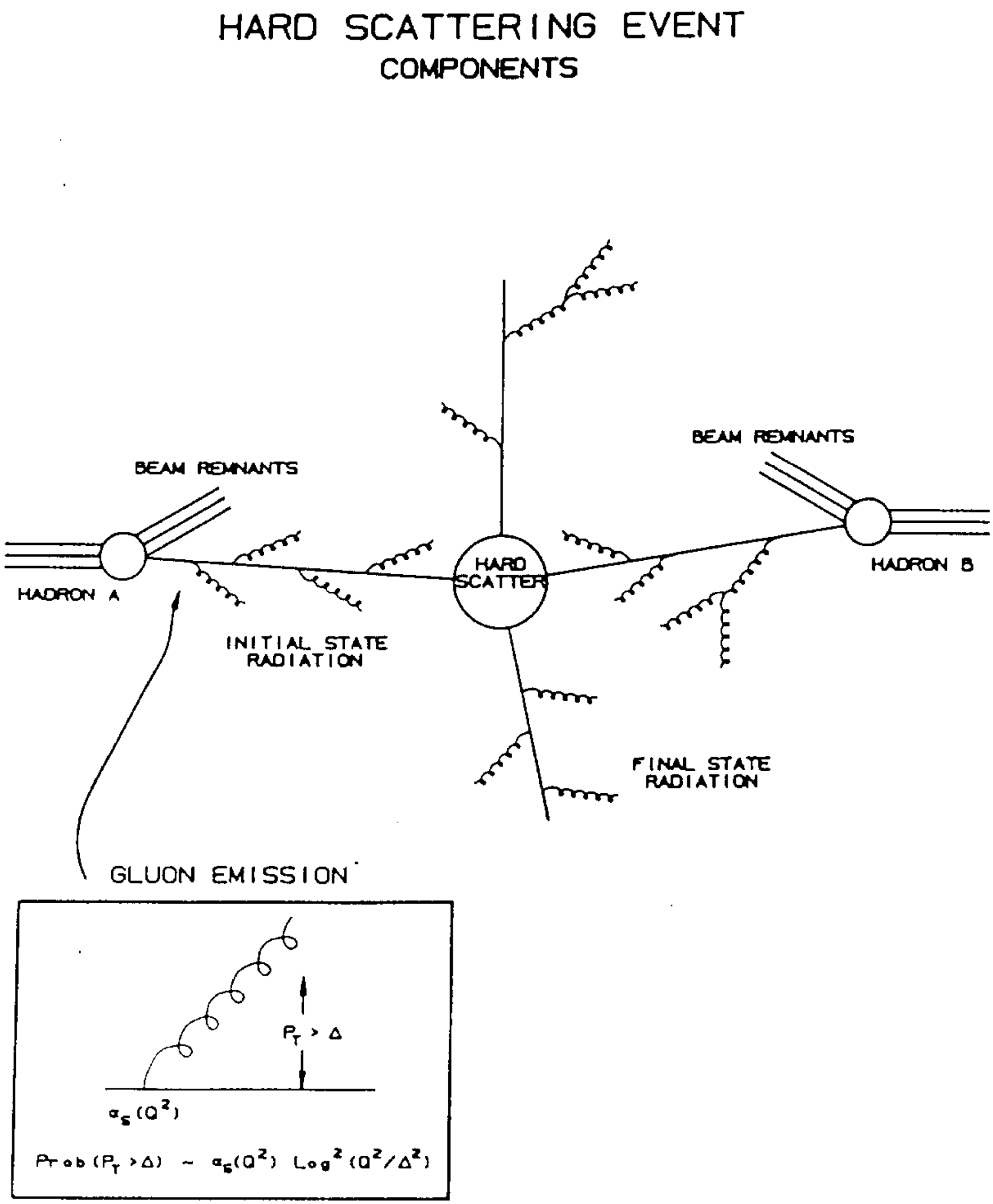


Fig. 1: Components of 2 to 2 hard scattering events.

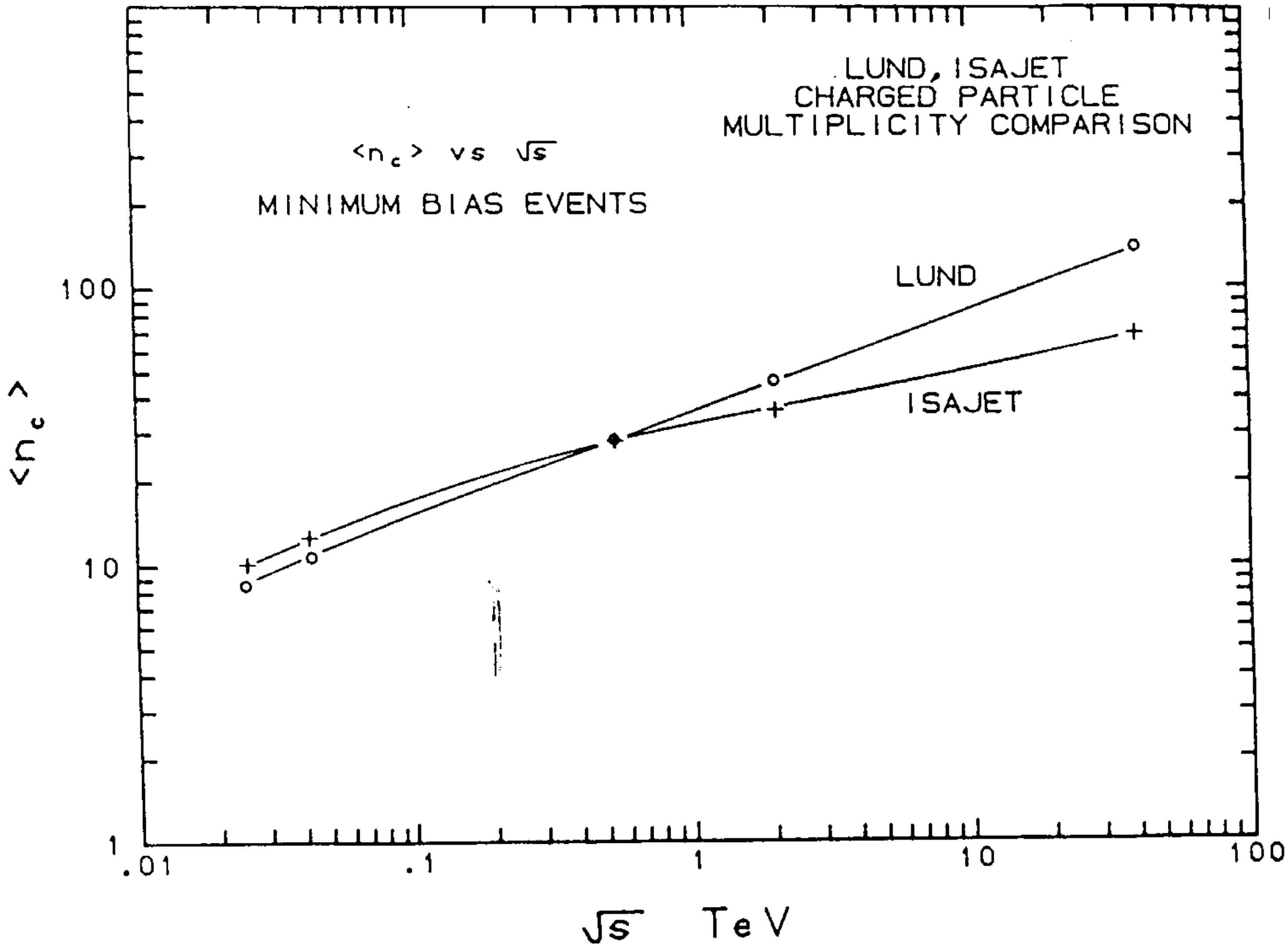


Fig. 2: Average charged particle multiplicities as predicted by ISAJET and LUND Monte Carlo as a function of $\sqrt{s}$

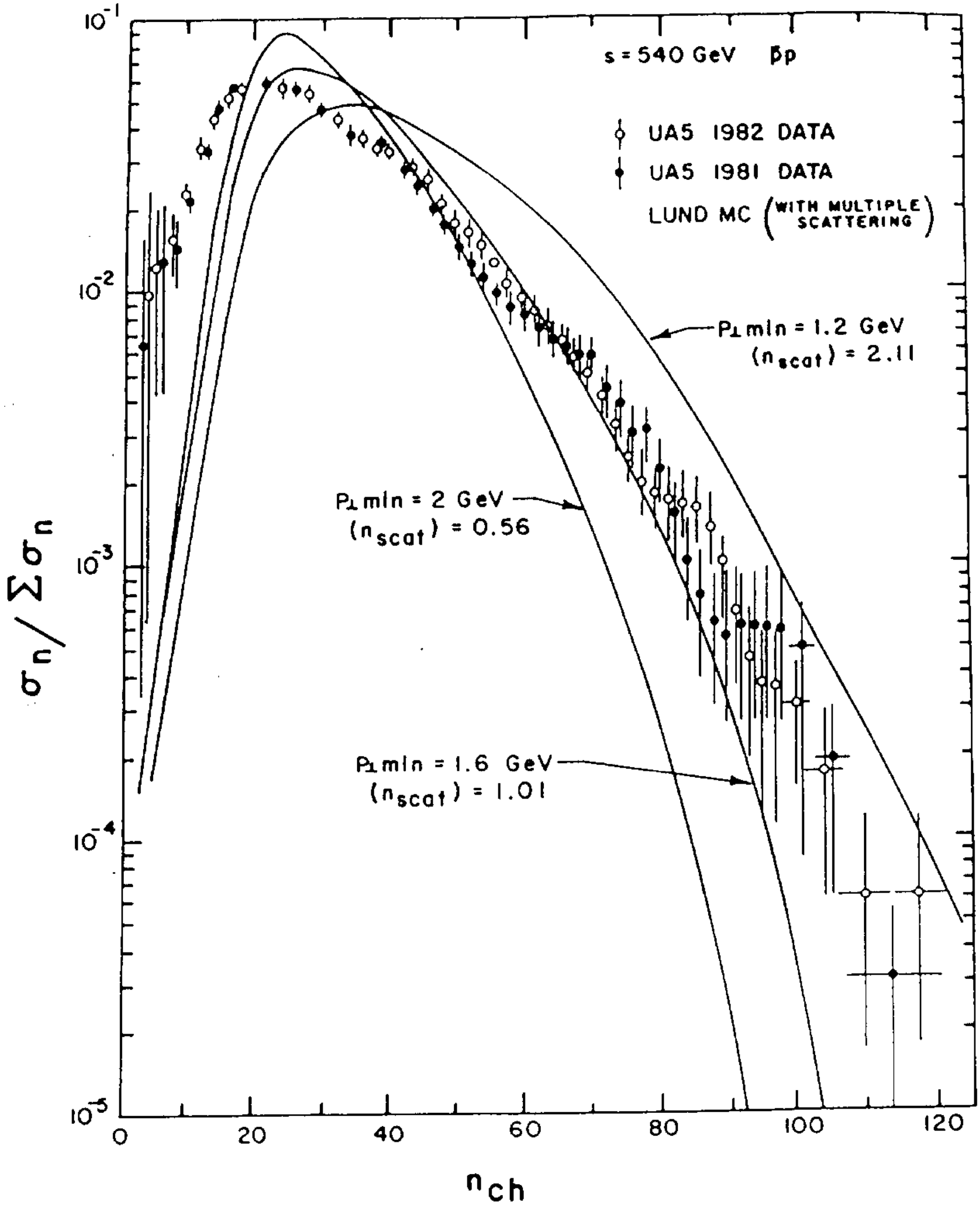


Fig. 3: Charged particle multiplicity distributions at s=540 GeV as measured by UA5. The predictions of the LUND Monte Carlo including the incorporation of multiple interactions between different pairs of partons in the beam hadrons. Three different p_T^{MIN} cutoffs are shown along with the number of multiple interactions that these cutoffs correspond to.

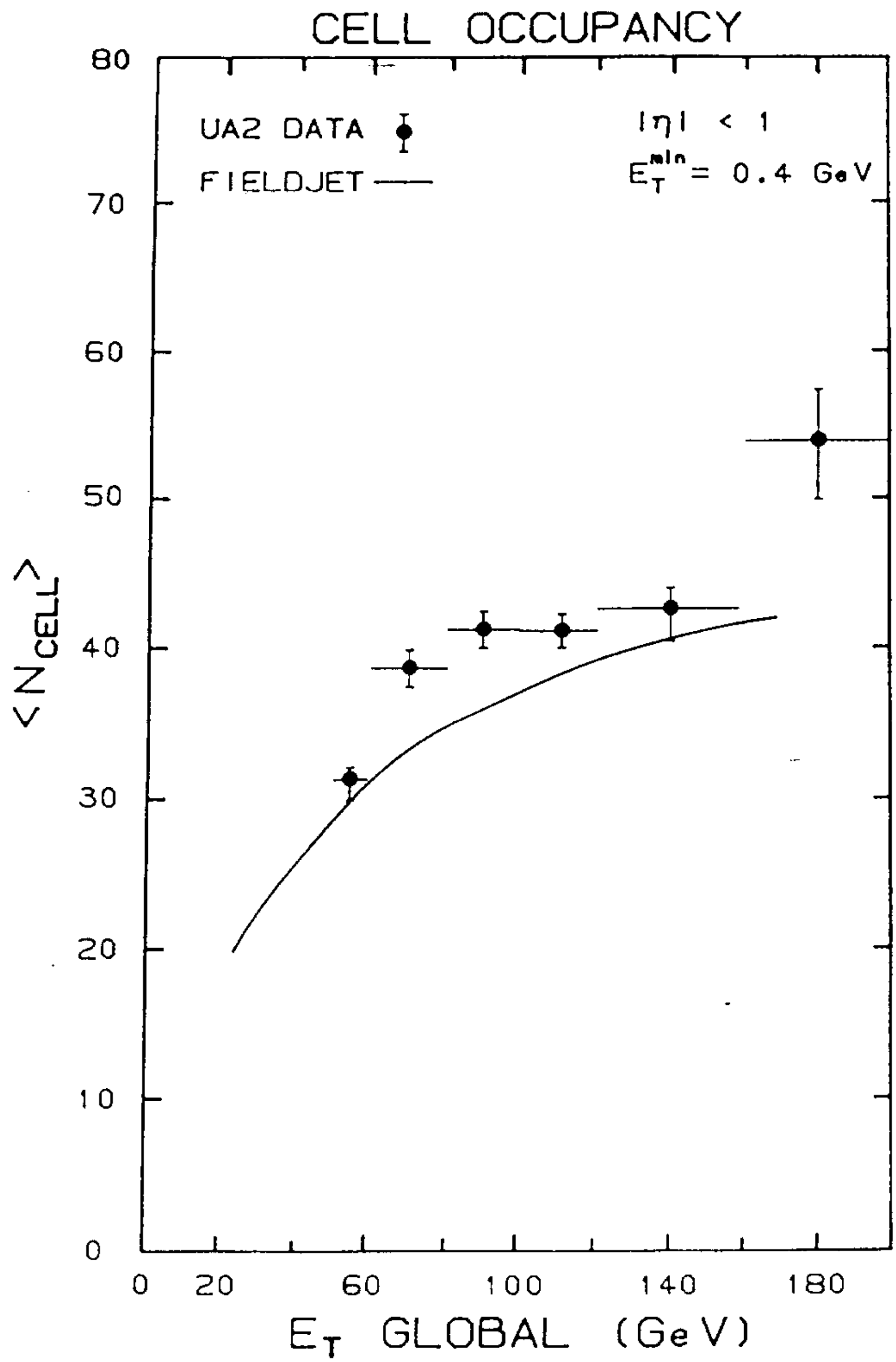
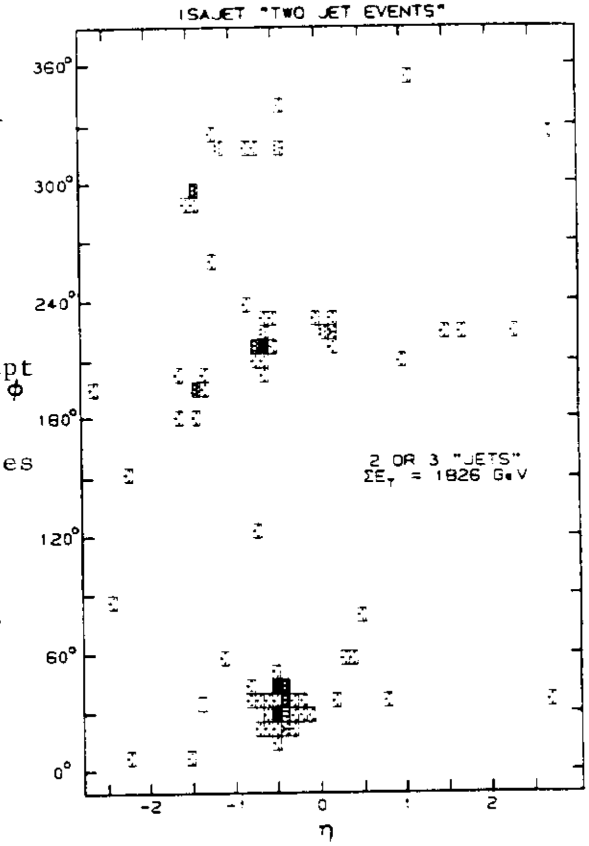


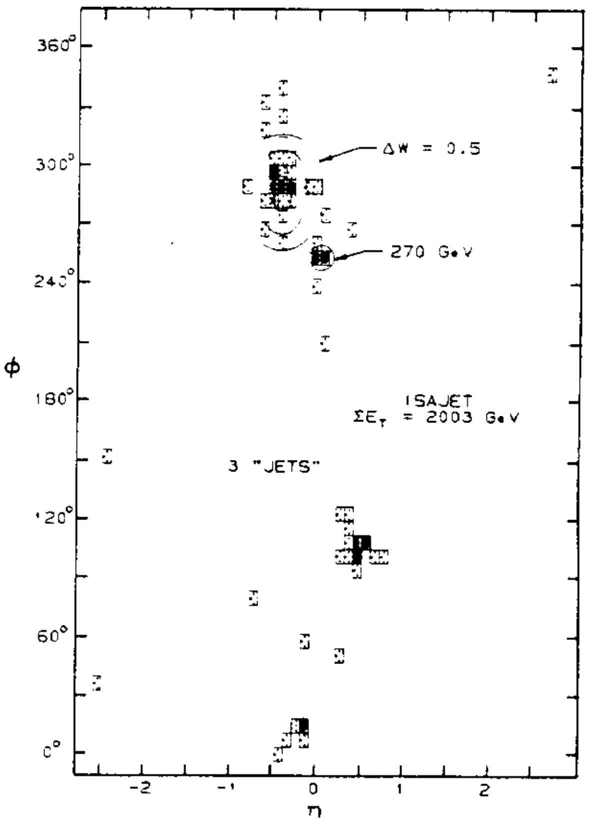
Fig. 4: Predicted occupancy of detector cells of size $\Delta\theta\Delta\phi = 10^0 \times 15^0$ from FIELDJET compared to data of UA2 at $\sqrt{s}$=540 GeV as a functionof global E_T. A cell is considered to be occupied if E_T within that cell is greater than 0.4 GeV.

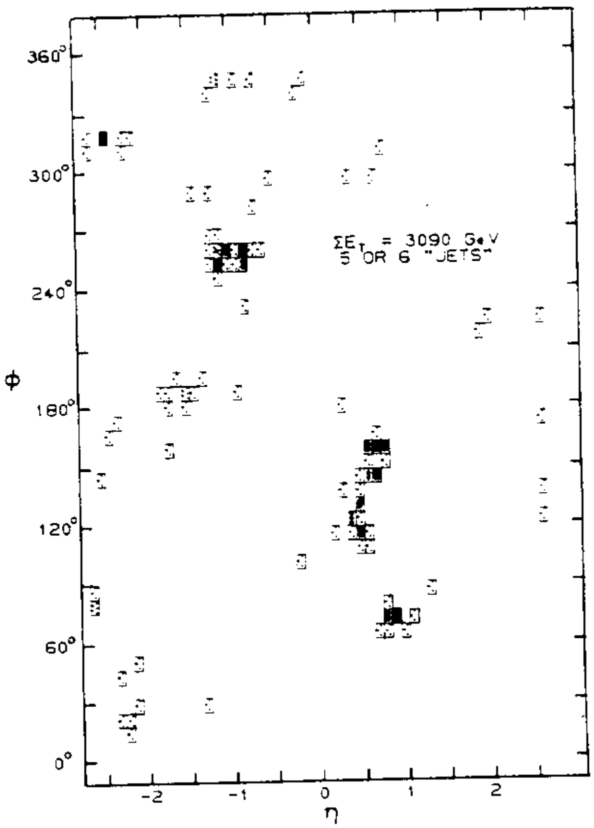
Fig. 5a: Typical high E_T event from a 2 to 2 hard scattering interaction as generated by the ISAJET at $\sqrt{s}$=40 TeV and displayed in the η, ϕ projection. This event appears to be a two or three jet event using the jet criteria described in the text.

5b: Another "typical" 2 to 2 high E_T event as described above except that there appear to be three substantial jets. The $\Delta\omega = \sqrt{(\Delta\eta)^2+(\Delta\phi)^2}=0.5$ contour indicates the area that a "reasonable" jet algorithm might assume for a jet size.

5c: Typical 2 to 2 high E_T event as described above which appears to have 5 or 6 substantial jets.







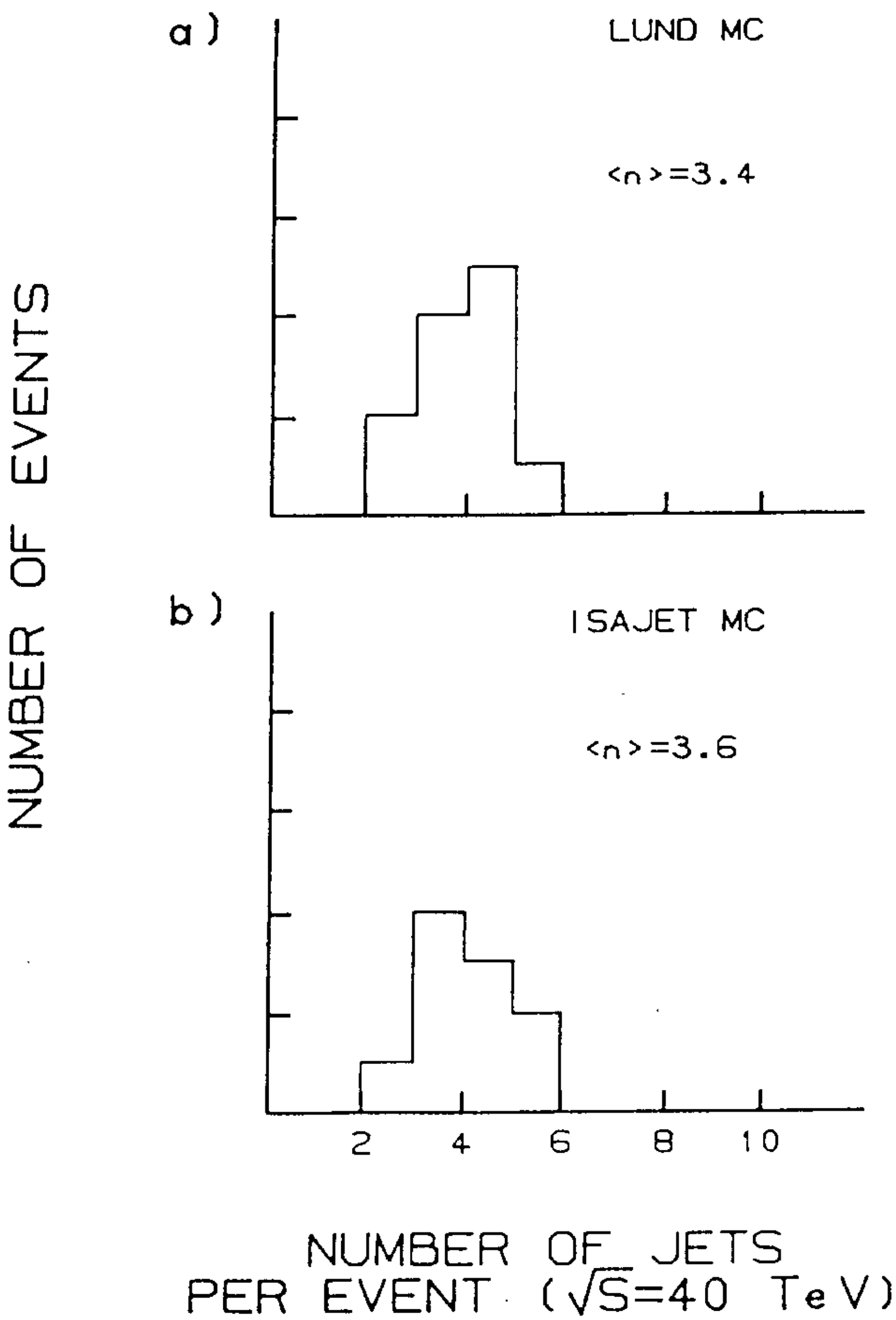


Fig. 6a: Distribution of number of jets in $\sqrt{s}$=40 TeV events generated by the LUND Monte Carlo as determined from the criteria described in the text.

6b: Distribution of number of jets in $\sqrt{s}$=40 TeV events generated by ISAJET as determined from the same criteria.

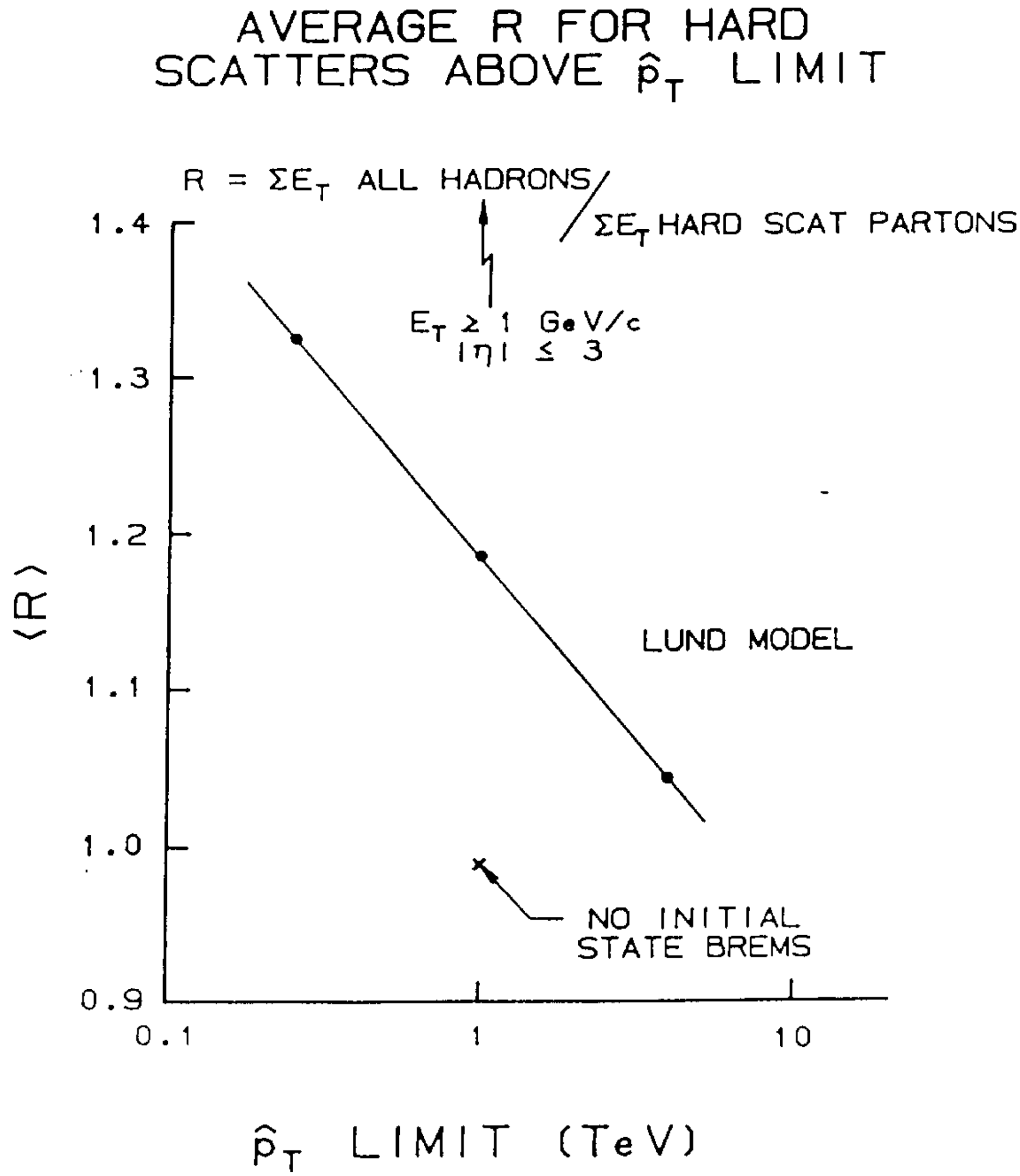


Fig. 7: Ratio of the E_T in s=40 TeV interactions generated by the LUND Monte Carlo to E_T in the hard scattered parton jets as a function of P_T for the hard scattering process.

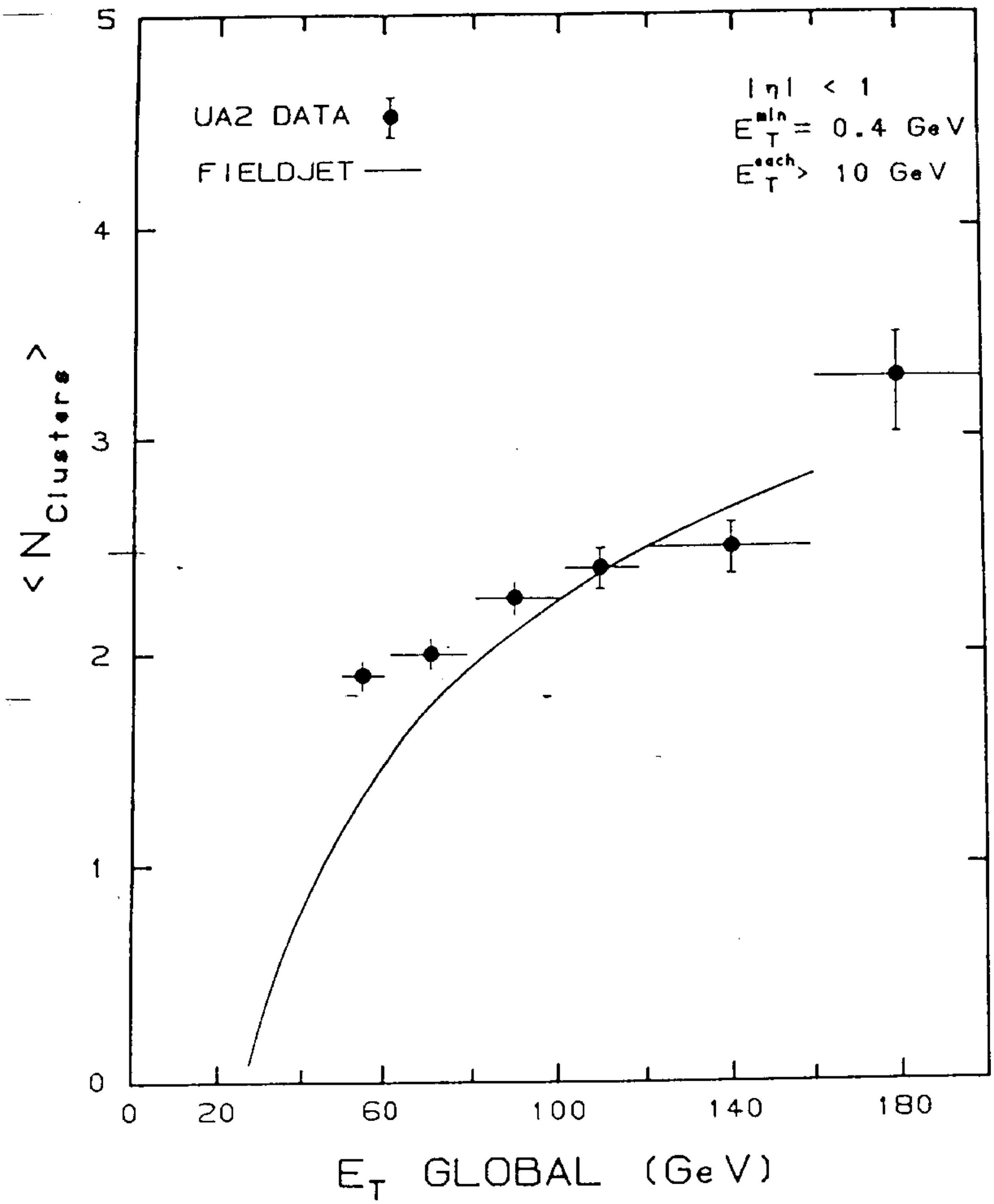


Fig. 8: Distribution of number of E_T clusters in $\sqrt{s}$=540 GeV $\bar{p}p$ interactions as a function of global E_T with E_T>10 GeV and $|\eta|$<1 as measured by UA2 compared with the prediction of FIELDJET.

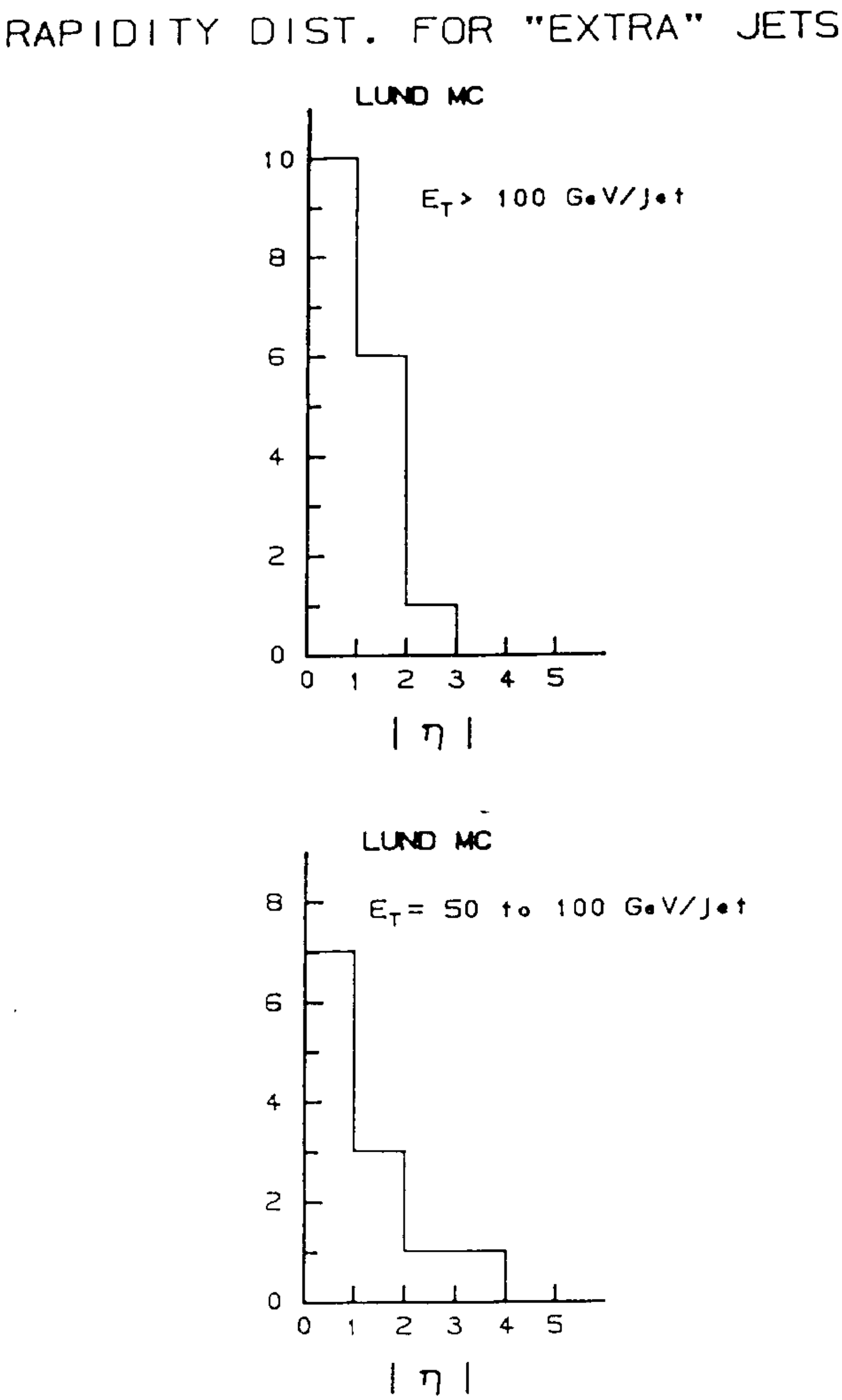


Fig. 9a: Rapidity distribution for jets with E_T>100 GeV other than the hard scattering jets as generated by the LUND Monte Carlo for $\sqrt{s}$=40 TeV pp interactions.

9b: Same as 9a but for jets with E_T>50 GeV.

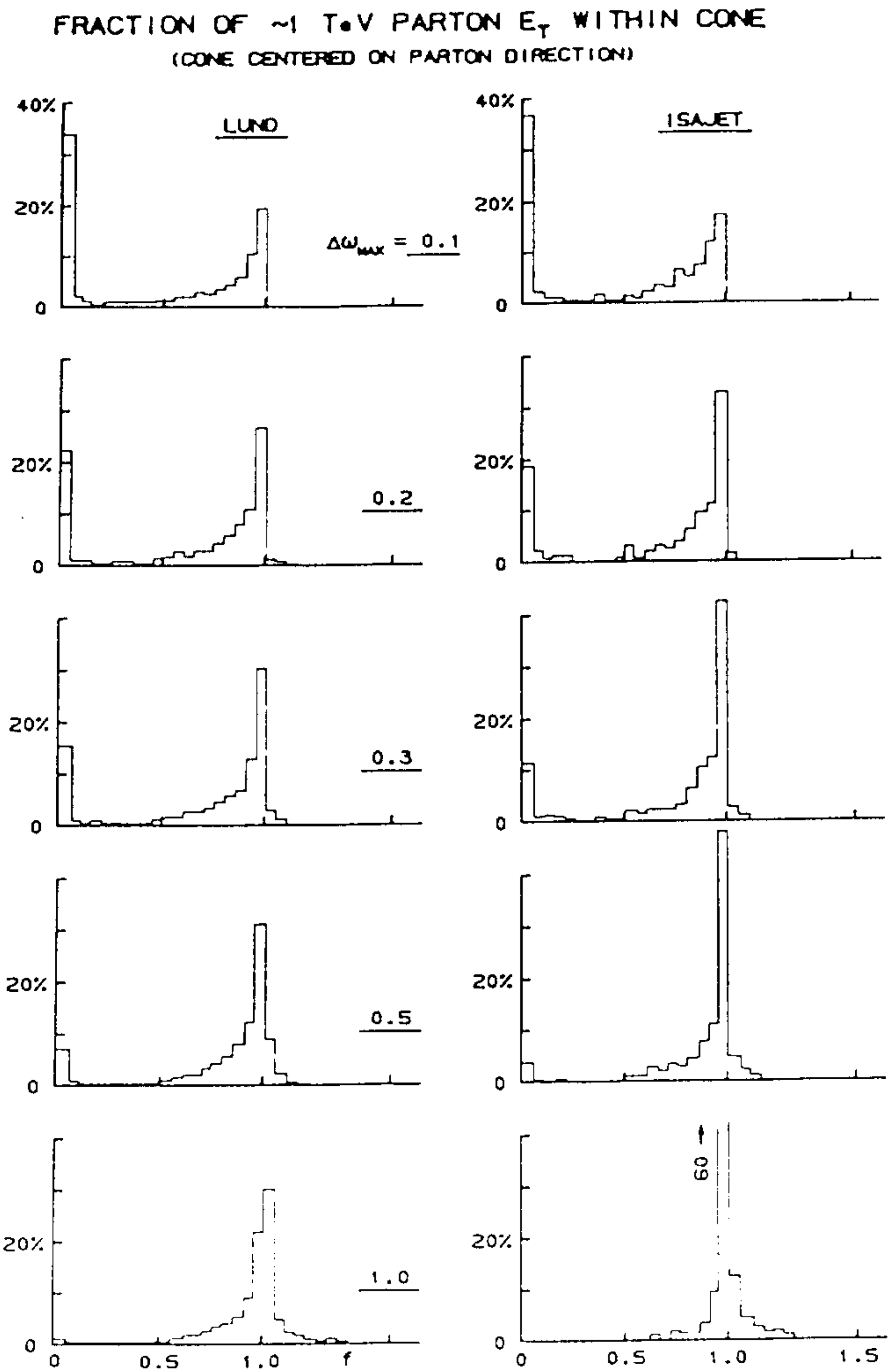


Fig. 10: Fraction of parton energy predicted by LUND and ISAJET to be within various $\Delta\omega=\sqrt{(\Delta\eta)^2+(\Delta\phi)^2}$ cones centered on the original parton direction.

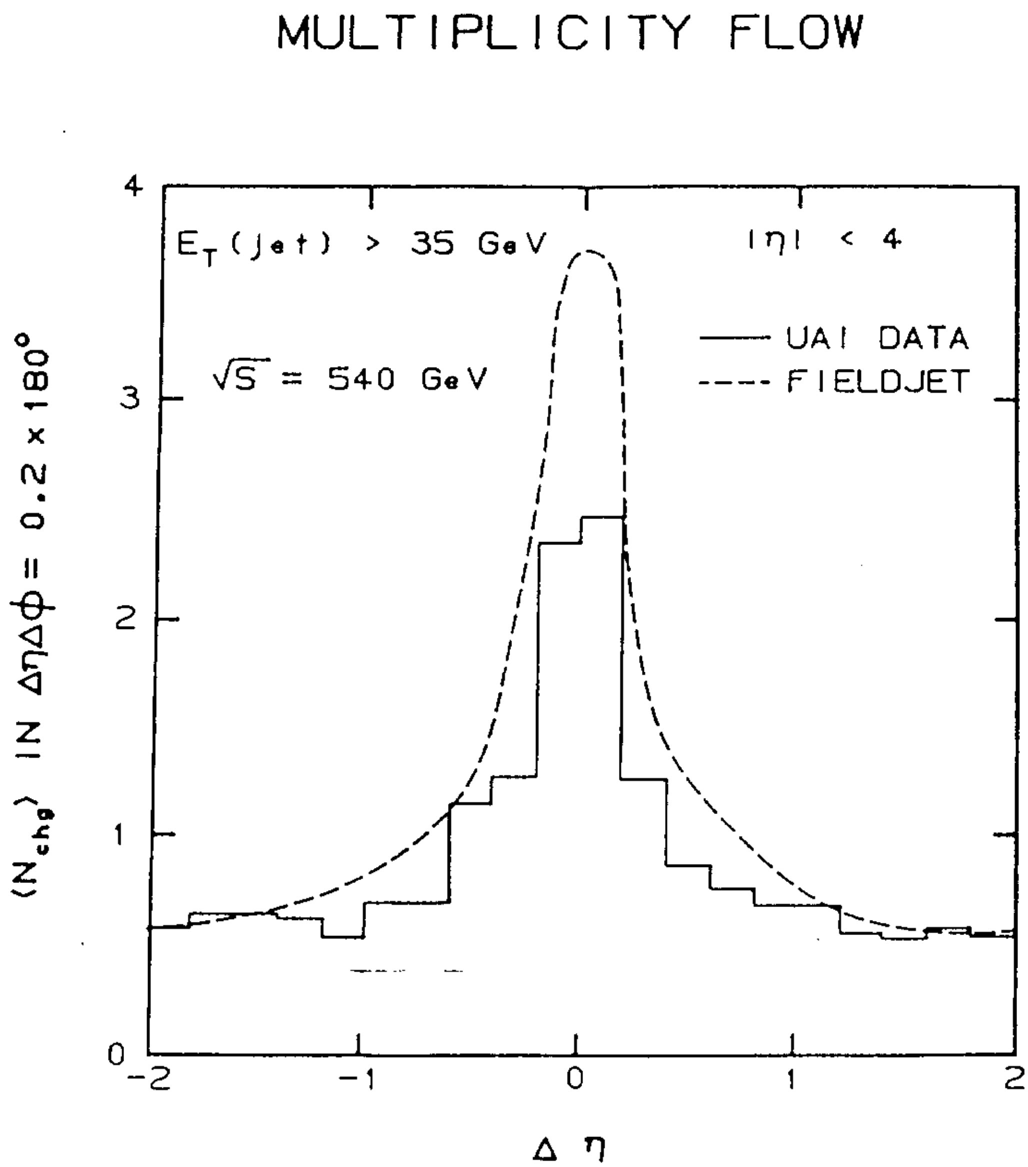


Fig. 11: Charge particle multiplicity flow relative to the highest E_T jet in $\bar{p}p$ collisions at $\sqrt{s}$=540 GeV with $|\eta|<4$ and E_T (jet)>35 GeV. Cell size of$\Delta\eta\Delta\phi$=.2x15^0 has been used. The data is that of the UA1 experiment and the prediction is that of FIELDJET.

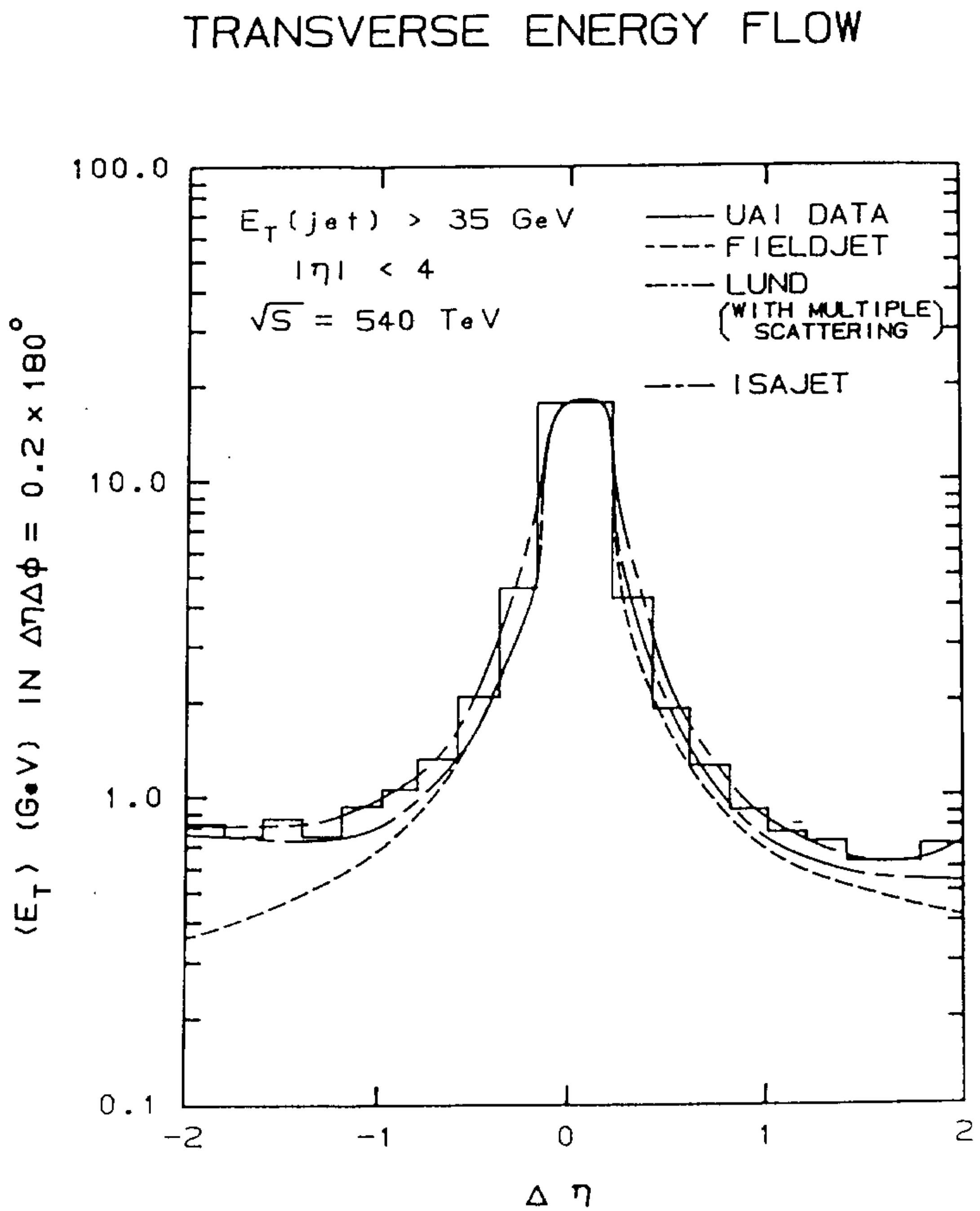


Fig. 12: Transverse energy flow with the same conditions as those of Fig. 11. The data is from UA1 and the predictions are those of FIELDJET (solid curve), ISAJET (dashed curve) and LUND (dot-dashed curve).

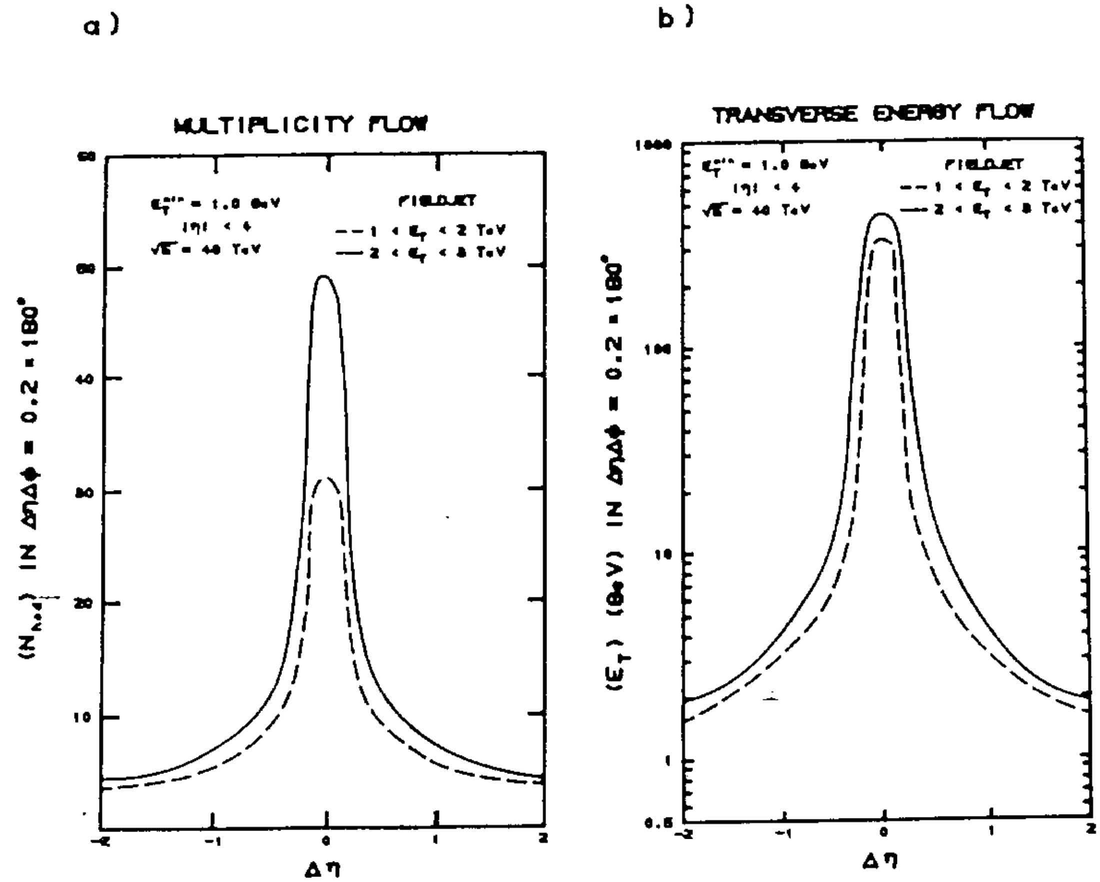


Fig. 13a: Charged particle multiplicity flow as predicted by FIELDJET at $\sqrt{s}$=40 TeV for global E_T less than 2 TeV and for global E_T between 2 and 3 TeV.

13b: Transverse energy flow as predicted by FIELDJET at $\sqrt{s}$=40 TeV for the same conditions as those of Fig. 13a.

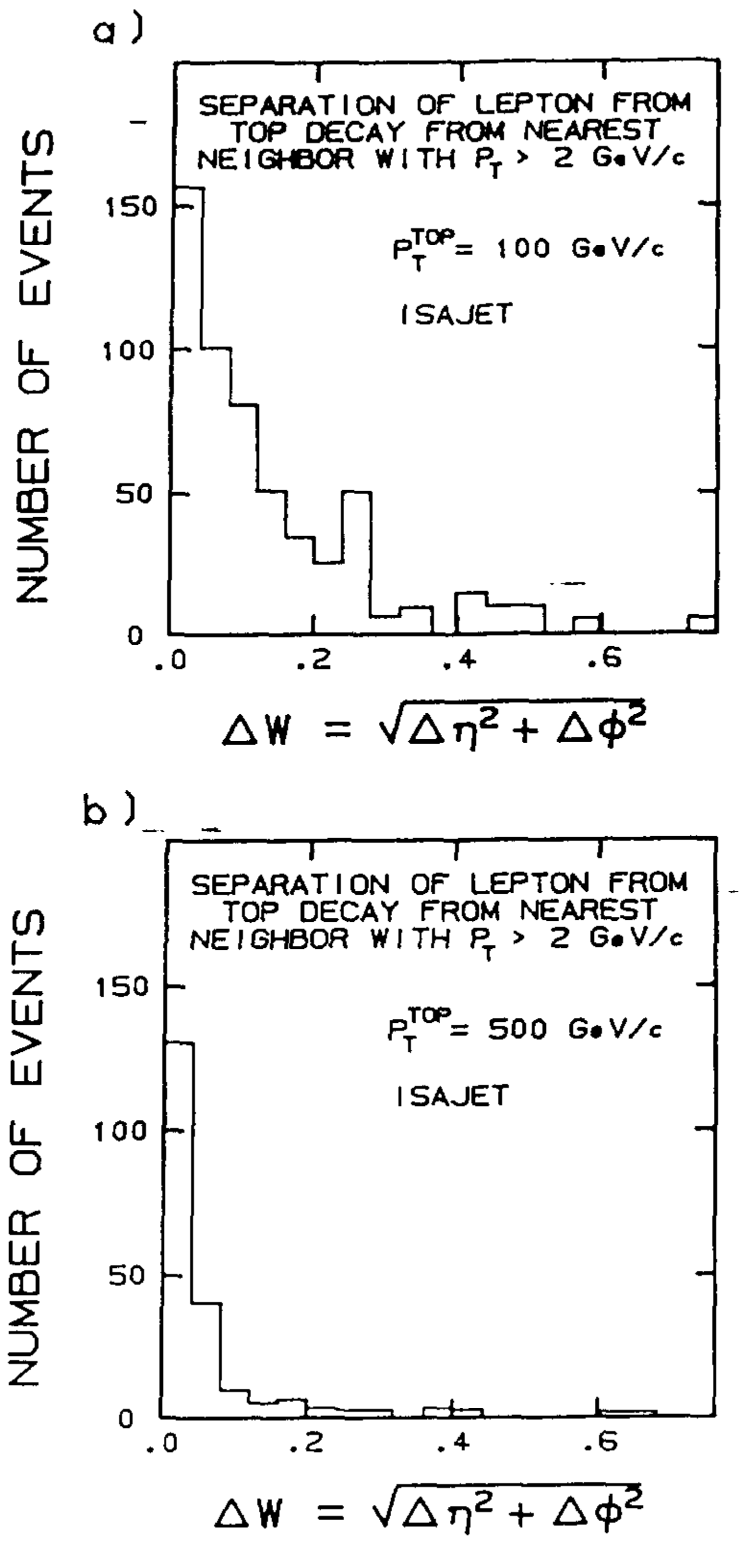


Fig. 14a: Separation of leptons from top quark decay from nearest jet fragments with P_T>2 GeV/c. Top quark P_T=100 GeV/c and minimum lepton P_T=10 GeV/c.

14b: Same as a) except top quark P_T=500 GeV/c.

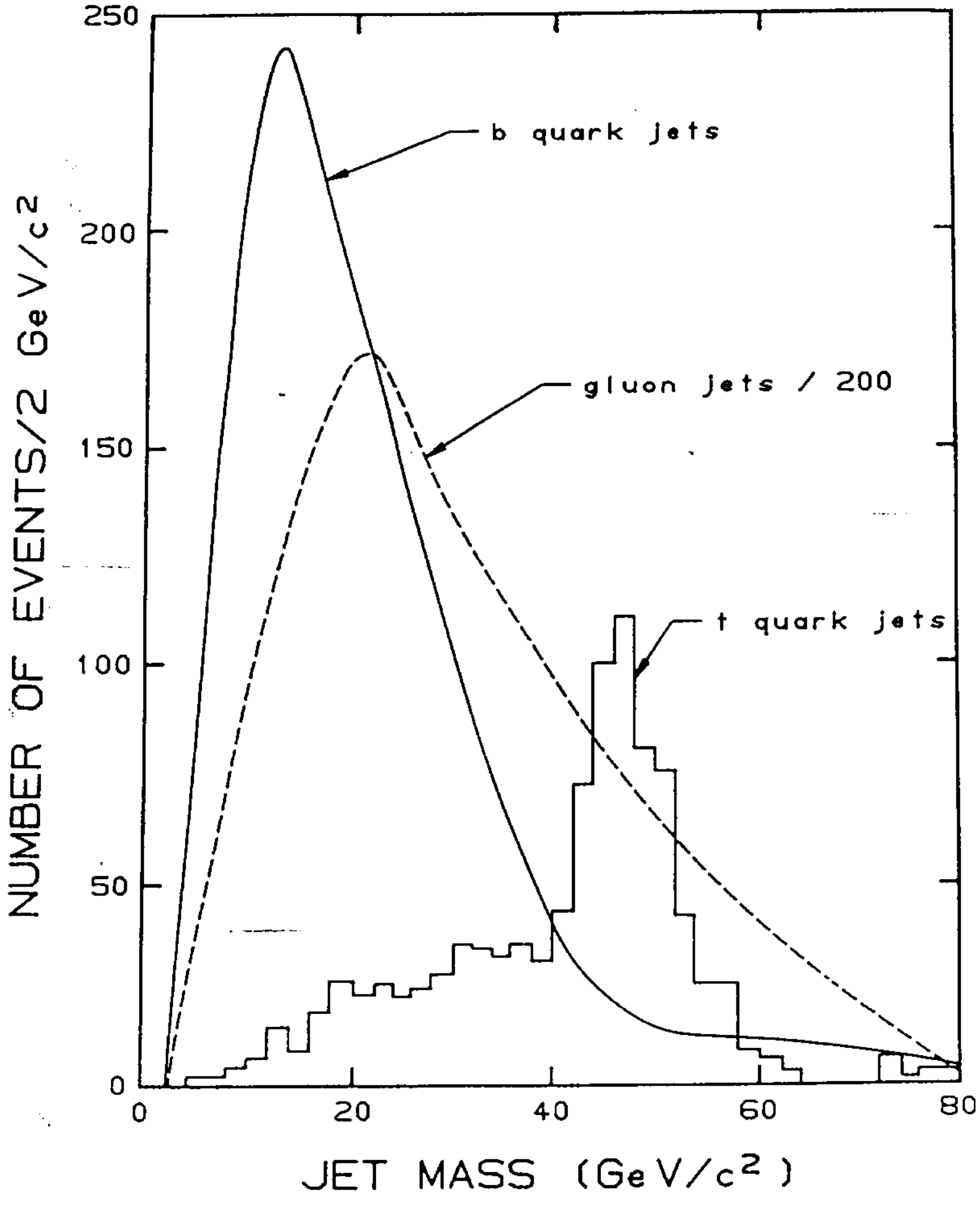


Fig. 15: Reconstructed top quark masses from gg → $t\bar{t}$ compared to expected mass spectrum of gluon from gg → gg.

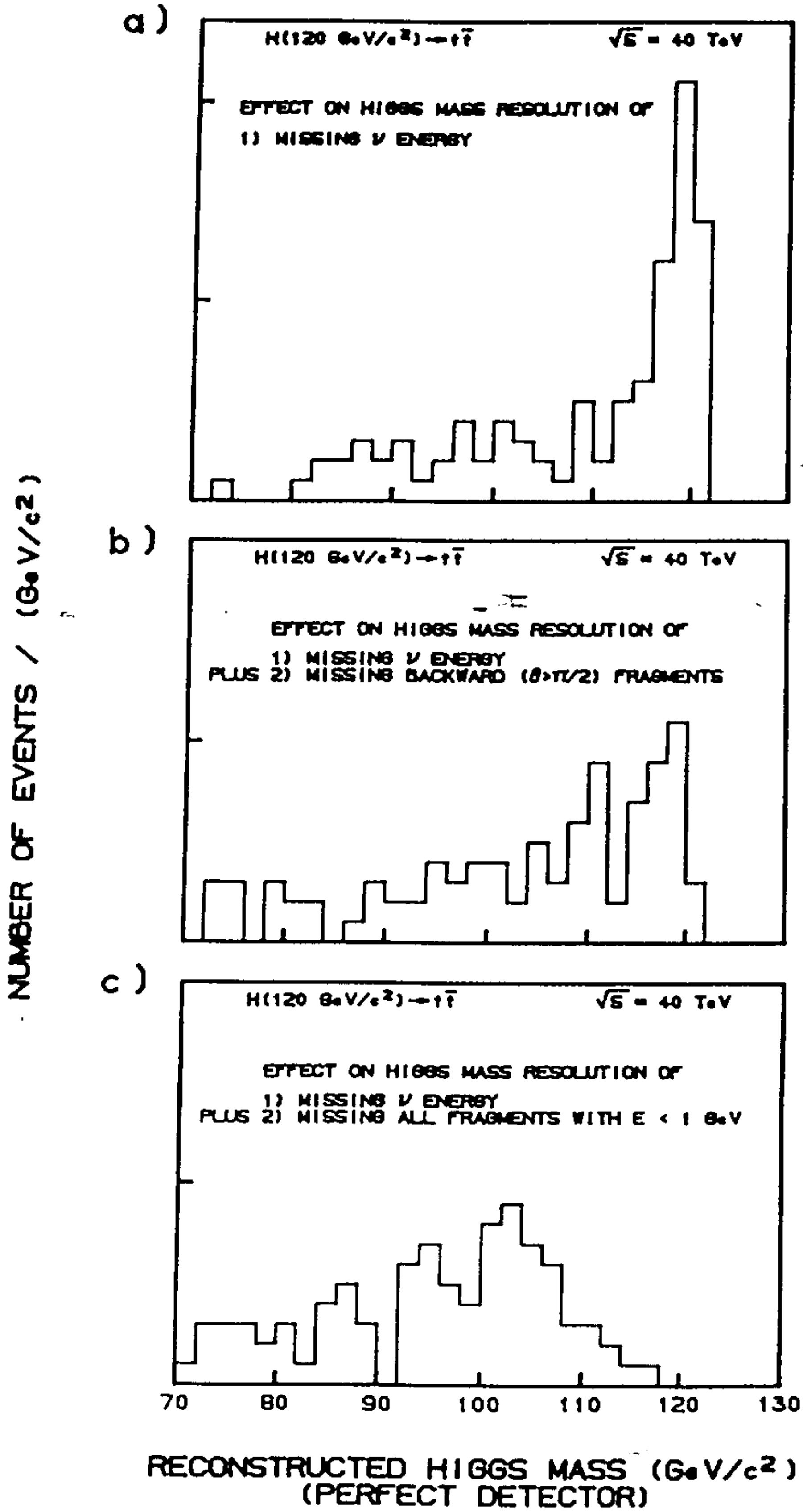


Fig. 16a: Effect of missing neutrinos from top quark decay on the reconstruction of the mass of Higgs → tt at $\sqrt{s}$=40 TeV for 120 GeV/c^2 Higgs.

Fig. 16b: Combined effect of missing neutrinos and missing energy in the reconstruction of the Higgs mass.

Fig. 16c: Combined effect of missing neutrinos and omission of all E<1 GeV fragments from the t quark jets on the reconstruction of the Higgs mass.

Figure 16